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ABSTRACT

The first (exploratory) phase of the Learning in Science Project focused on science teaching/learning in the Form 1 to 4 level (ages 10 to 14) and sought to identify problems and difficulties in several areas. Provided in this paper are comments obtained during structured/unstructured interviews (from students, ex-students, teachers, headmasters, science advisers, and inspectors) and observations made by project staff related to science experiments. The intent in presenting these comments/observations is not primarily to provide a balanced view of the good and bad aspects of Form 1 to 4 science, but rather to open up problem issues as project staff and others see them. Comments/observations are presented in three sections: (1) introduction; (2) experimental work and the learning of facts, concepts, and principles; and (3) experimental work and the teaching of process skills (including such scientific attitudes as open-mindedness). Included are questions raised by the comments/observations presented, focusing on how frequently children really appreciate the problem being experimentally investigated, purpose of experimental work seen by teachers/students, and other areas. Also included and discussed are two measures which may alleviate some of the identified problems. (Extracts from observer's notes/transcripts are provided in a short appendix). (JN)

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LEARNING IN SCIENCE PROJECT

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WORKING PAPER No 2.

The Learning in Science Project is an educational research project undertaken at the University of Waikato under contract to the NZ Department of Education. The project is initially investigating the problems and difficulties of Form 1 - 4 Science (10 - 14 year olds) as a first step to improving teaching and learning.

This paper is one of a set of essays which is an outcome of the exploratory phase of the project. It is our hope that feedback from these essays will assist further to clarify issues and assist us in establishing priorities for the in-depth phase of the project. Any comments our readers have on either the issues involved, or the methodology adopted in these papers, would be most welcome.

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A WORKING PAPER OF THE LEARNING IN SCIENCE PROJECT

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July 1979

This is one of a set of discussion papers which focus on various aspects of Form 1-4 Science. The paper collates comments and observations, related to the topic of focus, which were obtained during the first phase of the Learning in Science Project. In this phase we were particularly concerned about problems and difficulties in Form 1-4 Science and because of this the paper is biassed toward issues as identified by pupils, ex-pupils, teachers, headmasters, science advisers, inspectors as well as by our own observers. Our intention in writing the discussion papers is therefore not primarily to provide a balanced view of the good and bad aspects of Form 1-4 Science but rather to open up problem issues as we and others see them, to a limited but wider audience than the project team.

It is our hope that our chosen readers will be prepared to talk to us about the topic under focus in this paper in terms of the following questions:

(i) Are the issues we have raised important and central issues which are of general concern?

(ii) Are there other more basic issues, or other subsidiary questions, about the topic which we have overlooked?

(iii) Which aspects of the topic could we profitably analyze further in the in-depth phase of the project?

(iv) What possible solutions to some of the issues raised could profitably be the subject of further study?

INTRODUCTION

One of the underlying principles in the teaching of F1-4 Science is that

> "the full range of objectives can be achieved only through activity based programmes, that is through programmes where *doing* science is regarded as just as important as (if not more important than) learning *about* science."
>
> (Draft syllabus p.18)

Most teachers would agree with this, at least in theory, and there are teachers who operate successful activity based programmes which achieve a wide range of objectives. Most students too would support the idea that school science should involve them directly in 'experiments'.[1]

22/12/2[2] "the part I liked was doing experiments, you know, dissecting animals and that, because I didn't know much about it, eh? and I wanted to find out more about it ... I liked the practical side of it rather than writing."

[secondary pupil]

7/1/2 "It is better doing experimental work than theory"

[ex-pupil]

22/15/1 "you learn a lot more from an experiment than if they told you about it"

[secondary pupil]

The syllabus intent, and the above views, reflect sharply against a recently retired science inspector's view of the main problem with F1-4 Science:

58/1/1 "If you are looking at the situation in the classroom, the things that I have seen and which have worried me at the F1-4 level are the difficulty, or the impossibility, I am not sure which, of carrying out suitable practical work on the part of the kids (at both intermediate and secondary levels)... so this would be the number one problem. Why? What are the difficulties which prevent teachers from letting kids do experimental work? Science is not empirical in schools, there is no doubt about that."

While there are great variations between, and within, schools, 36/1/1 other comments have supported this overall generalization. Many pupils 43/4/2 have told us that they enjoyed experiments, when they did them, but 11/1/1 science lessons were often just listening, reading and writing: 13/5/2

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1 We were always told about 'experiments'. In their comments students, and teachers, tended not to distinguish between investigations, demonstrations, practical exercises, projects and so on.

2 Tape/page/section reference to original transcript on our files.

24/14/2
13/2/3
15/1/2 "I think some of the practical experiments I used to quite enjoy but we only occasionally did an experiment - a lot of it was just working from a book."

[ex-pupil]

Obviously there are physical difficulties and constraints which militate against a practical programme. Teachers mention lack of equipment, the difficulty of organizing equipment, time constraints and so on. For example,

20/9/3 "a lot of the problems are not problems with the syllabus, they are problems in just general management. A teacher that has had to come from a room two blocks away...open up a laboratory, clear a corridor of kids falling over bags, get them in, get them settled, send someone off to the technician to pick up a particular specialist piece of equipment...and so on before he can get started...and finish up slightly early, get the equipment back, tidy up the laboratory if he is a tidy teacher, and they all aren't... then move on to another laboratory the next period...you know, it produces frustrations for teachers."

[H.O.D. Science]

However are there often more basic problems with experimental work in schools when it is attempted? Let us first examine, in a little more depth, childrens' statements that they enjoy experimental work. While some students stated they learnt more from experiments than other classroom activities, we frequently recorded comments such as,

16/2/2
36/11/2 "we enjoyed the experiments but didn't learn much"

[ex-pupil, F2 pupil]

11/1/1 "we had fun, we just mucked around and made a mess"

[ex-pupil]

43/4/3 "I enjoyed the experiments, and that, it was fun ... but when it came to the theory I didn't like it...I just turned off as soon as that came"

[ex-pupil]

and associated teacher comments

22/2/3 "they had a tremendous time...they enjoy doing it...but afterwards they hadn't learnt anything"

[3rd year secondary teacher]

20/17/3 "the kids enjoy it but many of them miss the point"

[2nd year secondary teacher]

17/19/2 "as far as their attitude is concerned the thing to them is 'Is it fun?' 'Can we play with chemicals?', 'Can we have a good time?'... it is nothing to do with learning"

[1st year secondary teacher]

Related to these comments are comments about lack of thinking. Childrens' comments include,

16/3/2 "we just did the experiment and probably didn't really think about why we were doing it"

[ex-pupil]

15/11/2 "sometimes you didn't know what you were doing...he would write up on the board and then we would just follow through"

[ex-pupil]

Teachers too make comments on this;

8/2/2 "it is very hard to get children to think about what they are actually doing instead of doing things in a mechanical way"

[senior secondary teacher]

23/5/3
9/4/1 "it is hard to get children to think about what they have done and to make conclusions"

[intermediate school teachers]

21/9/1 "they often don't relate the practical work to the ideas that I want them to relate it to"

[P.R. Junior Science]

21/9/3 "I had put on the board what they were to do...when they came to do it they had no confidence...and they had to ask me again... How much of this? What do I do? What do I put together?...now I think that is an attitude that is quite common through all the levels"

[P.R. Junior Science]

Why do many science lessons apparently not require children to think? Suggestions are

35/5/1
4/1/2
58/9/3 (i) "the work is beyond them and they are unable to think at the level required"

[science inspector]

13/2/3 "I used to quite enjoy the practical (but) a lot of experiments I couldn't really see the point of any way...I just tended to do them...I probably got something out of them but not as much as I could have if I had really understood why I was doing them... often the instructions we were given were long and detailed and by the time you got to the end of them you were so busy

trying to remember the beginning that I was lost... we went through the motions but that was all it was"

[ex-pupil]

22/1/3 "I find even in the 4th form it can be very difficult to get across to kids the idea of control for instance...the fact that this gives some indication of what we are testing for...and well even with some 5th formers they still don't really know what it is all about...which suggests to me that they don't really know what they are doing when they are doing an experiment"

[3rd year secondary teacher]

25/6/2 (ii) "the work doesn't stimulate kids sufficiently for them to want to think"

[secondary teacher]

As a science adviser on an in-service course stated

64/9/3 "like we have just been outside for a nature walk and we had a list of questions to answer, but I wasn't particularly interested in those questions, but I was interested in other things that were out there"

What is being suggested is that children will not really think about what they are doing, at least in the way we want them to think, unless they identify themselves with the investigation - unless it has become *their* investigation. As suggested by an experienced teacher..."it requires time and effort to ensure that the teacher formulated problem is internalised by the student - for the student to identify with the problem."

(iii) the work is not perceived as requiring thinking, it is an intellectual game where you follow instructions and try to find the 'right answer'

Many children seem to see experiments as an activity where you follow instructions and if you follow them correctly you will get the 'right answer'. The right answer is known before you start by the teacher. Following instructions can be fun

20/26/3 "a lot of people were not thinking about it...they were just treating it as a bit of a game"

[F3 pupil]

however to others it can be worrying or frustrating

12/11/2 "I hated experiments...I was afraid I might do something wrong... if anything was very vague I wouldn't attempt to try it"

[ex-pupil]

12/7/2 "I liked doing experiments, as long as I got the right answer"

[ex-pupil]

The comments provided in this introduction suggest that there are problems and difficulties with experimental work far beyond the frustrations and difficulties that teachers have in organizing practical work. To proceed further with our discussion we need to ask what is the purpose of experimental work? What are we trying to achieve? Possibly the answer is not clear just as the purpose of experimental work is not really clear in most science courses. As Tampion (1977)[3] suggests about Nuffield Combined Science "It seems to me that a crucial fault of the course is a failure to think through the whole idea of experimentation and its place in the teaching of science." This seems closely related to the following comment

35/6/2 "I don't think the teachers have sat down and thought out why they are doing experimental work."

[secondary inspector]

For this reason, it may be useful to analyze experimental work in terms of the various objectives of the draft syllabus.

EXPERIMENTAL WORK AND THE LEARNING OF FACTS, CONCEPTS AND PRINCIPLES

72/3/1
58/6/2 On the basis of our interviews and classroom observations it appears to us that most teachers use practical work primarily as a vehicle, or an aid, to understanding science content. The idea of 'discovery learning' or 'guided discovery learning' was frequently mentioned by teachers, particularly intermediate teachers, but also by many secondary school teachers. Let us consider some viewpoints put forward by teachers

22/4/1 "Everyone who has been to training college thinks the discovery approach is absolutely marvellous but I have found it only frustrates the kids"

[3rd year secondary teacher]

24/1/2 "I found I could teach discovery quite easily with younger kids whereas at high school I found I just couldn't do that"

[primary/secondary teacher]

41/1/3 "(the next unit) is going to involve a lot of, sort of experimenting, and, sort of having to guide the children, so that they are going to make hypotheses and then, sort of guide them again, so that they are going to come up with the right sort of answers. Well, if you don't

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3 D. Tampion, School Science Teaching: is there any? New Scientist 30 June, 1977, p.782.

know yourself what are the right sort of answers to come up with, how are you supposed to sort of guide them?"

[intermediate teacher]

In view of the above comments, and the earlier comments quoted, what appears to be the problem with the discovery approach to learning science content? Various factors that may individually, or collectively, cause problems have been suggested to us:

35/5/1
18/2/1
58/10/1

(i) The ideas to be 'discovered' require such a complicated experimental design or such complex instructions, that children can't understand the experiment or identify with it. [inspectors, teachers]

39/3/2-4/1
23/10/2

For example some children have difficulty appreciating the idea of control or control over variables (see Appendix A1 for an example). Children can be found following instructions with no clear overview of what they are doing or why they are doing it (see Appendix A2 for an example). Not only are the children uncertain but sometimes the teacher isn't certain either,

39/4/1

"I am sure, that earlier on in my teaching that I used to just go through the motions of doing a lot of activities...not really knowing where I was going"

[8th year intermediate teacher]

(ii) Teachers can be apprehensive that the children will not obtain the right answer to support the theory which is being "discovered", and children can be apprehensive too.

17/18/2

"Practicals are of tremendous value if you get the result you want from them - you can't always guarantee that...often they are extremely time consuming to set up...to prepare for them before hand...to actually go through it you probably use a whole period on just one practical and in the end may be 50% will get the result which would be considered correct. But I feel audio-visual aids can help bring the topic or the concept that much more to life."

[1st year secondary teacher]

24/8/1

"That's one of the biggest problems. They [teachers] think it [the experiment] has got to work, and what if it doesn't work? How do I explain away something that doesn't work?"

[intermediate/secondary teacher]

45/5/2

"There were some experiments, it doesn't matter which way you did them you just could not get the result that was in the text. This upset quite a few teachers [and] I think children probably react the same way."

[senior intermediate school teacher]

26/7/2 "the shy ones hesitate to make a conclusion just in case they are wrong"

[secondary teacher]

12/15/2 "I was scared of actually doing it wrong...you know if the thing was so vague and I wasn't quite sure what to do"

[ex-pupil]

35/6/1 "there is a tendency to rubbish kids who don't get the right answer"

[secondary science inspector]

As we observed this emphasis on the 'right answer' can have most unfortunate side effects on other objectives of science teaching [see for example Appendix A3] , as well as on the teaching itself [for example over structured instructions] .

(iii) <u>The ideas to be 'discovered' from an experiment do not follow from the experimental evidence that children obtain or the ideas are conceptually beyond them.</u>

58/1/3 "I think we should try to teach basic concepts, we should try to teach it empirically but I see more kids making trivial judgements on trivial evidence and I don't think they have got anything out of it"

[secondary science inspector]

9/4/2 "Another problem is where we're doing experiments and to get children to conclude evidence from the result...I find it quite hard to get children to actually see oh, that's what has happened and that is why it has happened"

[experienced intermediate teacher]

20/23/1 "Very often they can see the physical result but drawing the conclusions from these results - which requires a bit of thought... that is often quite difficult"

[2nd year secondary teacher]

23/5/3 "The crunch comes when they have to record or interpret or make notes...and it is that side of it that we find is not developed... sometimes it is not there in F2 possibly not in F4 and there in lies the problem with the discovery approach"

[experienced intermediate teacher]

38/6/2 "The experiments didn't give them the experience and the kids didn't have the intellectual ability to even begin to see what we were taking for granted in asking the questions"

[secondary science inspector]

(iv) Teachers make broad generalizations to support theory on trivial evidence from experimental results.

58/6/3 "[the kids are often given] very trivial minor experience on which to build their generalizations"

[secondary science inspector]

This phenomena is something we too have observed in classrooms. For example in one classroom camphor heated on the front bench was smelt first by children in the front of the room and then later by children at the back of the room. A *conclusion* of this experiment, written on the
66/11/2 blackboard was "All matter is made up of small particles".

One point suggested by the above comments and observations is that there may often be a *forcing of the discovery approach* leading to 'pseudo-science'. Could it be that the theoretical ideas that one is trying to teach, particularly at F3 and F4, cannot be 'discovered' in many cases from the type of experiments appropriate for school science i.e. conceptually simple, inexpensive and capable of being completed in a 45 minute or 1 hour period?

Is an empirical approach desirable for the teaching of concepts and principles and, if so, what sort of approach should this be? One view is that the purpose of practical work for the teaching of theory is to provide *experience* upon which scientifically generalizations can be meaningfully *taught* and understood, i.e. not necessarily as a direct basis for the generalization but so teacher and pupil can relate ideas to a common experience which they have shared.

58/7/3 "If a kid does a dynamics experiment and comes to the conclusion that the force is inversely proportional to the mass, and directly proportional to the cube of the acceleration [instead of proportional to both!] so what? They now know what the hell I am talking about when I talk about force and the effects it produces...and this word has a meaning because they have now measured it and tried to calculate it...I don't mind...at least the kid can say I now know what you are talking about"

[science inspector]

This view is reflected in the following student comment

36/6/2 "I think as well, that the experiments you do are too much orientated to fitting into a theory and making up a theory. I think for other things you need experiments to show this is just what it is like...you don't have to worry about proving a theory...you just want to show someone what it's like...this is what it looks like"

[6th form pupil about F1-4 science]

The above approach is fine if the experimental work is followed by teaching and meaningful discussion. Unfortunately if the experimental activities are followed by no generalizations, or by generalizations which the pupils cannot relate to what they have experienced, the children are left wondering what it was all about and the teaching opportunities provided by the practical experiences are lost. As one science inspector
35/3/2 stated "In some cases there is too much practical and no theory". Alternatively at the F1 and 2 level, in particular, there may be insufficient guidance for the discovery of, or familiarity with, *scientific* ideas to begin to occur.

23/2/3 "I think that all teachers can see the benefit of the discovery approach but it is not until you witness and come to grips with a shambles that you set up in your own room that you can really learn from it"

[experienced intermediate teacher]

The problem of teachers not being sure where they are guiding to has already been mentioned.

In summary, teachers do find it hard to teach concepts using an
9/4/1
38/11/2 empirically based approach, partly because you have to know 'an awful lot
27/4/2 yourself', partly because the resources required may not be available,
18/1/2 partly because the organizational problems of laboratory, equipment, children
20/8/2 and time are great, partly because often too much is expected of experiments
38/5/3 and pupils in terms of discovery science but perhaps most of all because we haven't thought out the place of experimental work in the teaching of
35/6/2 theory and, associated with that, what theory it is appropriate to teach by this method.[4] Possibly an experimentally based approach to science which is attempting to teach basic concepts is not, and cannot be made suitable for the pupils in the lowest third of the ability range;

58/2/3 "I don't think it is on for them...I don't think they will ever ...never mind now, reach the intellectual maturity to cope with it..."

[secondary science inspector]

EXPERIMENTAL WORK AND THE TEACHING OF PROCESS SKILLS[5]

The draft syllabus places emphasis on the processes of scientific enquiry and on the mental approach to scientific work which competent

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4 This topic will be explored further on in the working paper FOCUS ON KNOWLEDGE.

5 Process skills will be taken here to include those scientific 'attitudes' associated with experimental work e.g. open-mindedness.

scientists are assumed to have. Apart from a few experiments at the beginning of the year to teach simple practical skills our observations suggest that little practical work is specifically designed to teach a skill or attitude directly. Rather in many cases experiments are designed to teach an aspect of theoretical knowledge. If incidentally a few process skills are acquired, well and good. As a secondary science adviser

6/12/3 put it "we pay lip service to skills". Other comments include

21/10/3 "We are doing a lot of experimental work in the 3rd and 4th forms but the kids are not learning experimental method and experimental methodology...we are missing a big thing...we are doing a lot of practical work but the processes that we are using are not always made obvious to the kids or want to be remembered by the kids... there should be perhaps a few more ideas where people are asked to design simple experiments to test simple problems."

[P.R. Junior Science]

23/10/3 "teaching them to do experiments from a skill point of view, or from being objective in their attitude, or design a controlled experiment themselves, that is very difficult"

[4th year secondary teacher]

26/7/3 "the kids that can organize themselves, adapt themselves nicely to organizing experiments and the ones that can't they just don't; whatever you do about it"

[senior secondary teacher]

17/23/3 "they [F4] haven't even grasped the fundamental scientific procedure of observation, setting up a hypothesis, and testing it someway and drawing conclusions to prove or disprove their hypothesis... I think a certain number of them aren't capable of doing that anyway...they really aren't capable of retaining that sort of approach...I could tell it to them one day and it would be lost the next"

[1st year secondary teacher]

These ideas of experimental design and so on are no doubt sophisticated. What about more basic skills of practical work?

8/4/2 "Some children have difficulty developing manipulative skills so when you go along to him in an experimental situation and find him fumbling the teacher has to be sensitive and observe this is happening and do something about it...but I don't think we get enough opportunity to do this enough"

[experienced secondary teacher]

17/12/3 "the recording of work shows no care and no accuracy... I think the failure here is that we don't insist on these basic skills; care of records, care of presentation is no longer insisted on, which I think is a move in the wrong direction... because I think that has a tremendous carry over"

[experienced secondary teacher]

17/4/2 "they are meant to be learning all these skills but when they get to the 6th and 7th [form] they are atrocious"

[H.O.D. Science]

25/10/3 "kids miss out instructions, won't follow or can't follow instructions"
73/3/3

[secondary teacher]

17/3/2 "even though these kids are very bright they still need direction - just give them the equipment - 'there you go, go and do it' and they are still coming up to me and saying 'will I copy this down? will I answer this question?' and I am saying 'I shouldn't have to answer that because here is a question with a question mark...you don't have to ask me whether you answer that question - of course you answer that question. That's your work - just little things like that."

[H.O.D. Science]

12/15/2 "we were never taught how to use the instruments"

[ex-pupil]

In terms of the right mental approach to scientific enquiry it is easy to see how some of the 'pseudo-science' mentioned earlier will actually encourage very bad scientific habits in children (e.g. Appendix A3). A few teachers are beginning to think how they might assess some of these "scientific attitudes and predispositions" and this is leading them back to consider; "What are we doing in our teaching to develop these attributes?":

25/15/1 "One of the things we wanted our kids to get exposed to was something about processing in respect to data...I must insist that the kids explain the unexpected result, I have got to question the genuineness of data if it fits the ideal thing too closely and that sort of thing...if my programme allows for that I have a programme that will help...that is consistent with the good attitude...but if I am telling the students what the results are and what conclusions they should get from those results in some way, or if I ignore results because they don't fit the pattern, or say that those results are wrong or no good, then I am setting up a situation that is consistent with a bad attitude as far as the data is concerned"

[H.O.D. Science]

This perception seems to us to be rare in teachers, and where the prime aim of laboratory work is to teach theory one can easily see how the teaching

of scientific processes and attitudes can suffer. Perhaps we need to think more about providing some experimental work, investigations or projects where the prime aim is not to teach theory but is to develop specific process skills and scientific attitudes? Where students are aware of what is expected and are aware that they are not expected to get a 'right' answer.

EXPERIMENTAL WORK AND ATTITUDES TO SCIENCE

Many pupils do say they 'enjoy experiments' but is this simply because they provide light relief from sitting on one's backside and writing? Enjoyment must not be confused with satisfaction, or with competence and associated confidence which leads to children to become enthusiastic about science.

At least in part, students' attitudes will reflect teacher attitudes, and attitudes developed through experimental work will be influenced by teacher attitudes.

41/25/2 "I think the teacher being enthusiastic toward science helps to develop a good attitude"

[first year intermediate teacher]

41/17/3 "I think if you can show enjoyment to the kids they will enjoy it too"

[intermediate teacher]

41/2/3 "the children are supposed to discover...and I think it makes children insecure in a lot of cases...they don't know what is expected of them...children like things in black and white...you know...I used to anyway and still do...it is sort of not clear cut in science you know...there is always that sort of haziness about it...I have got a negative attitude towards it you know...anything science."

[intermediate teacher]

One of the major problems that teachers identify in their science programmes is how to motivate children, how to make science interesting. One difficulty seems to be to get children to see the problem being investigated as a real problem, and then to feel that they have succeeded in solving it. For this to happen, the problem must be within the intellectual range of the child, and also within his range of interests (albeit with some stimulation!)

36/9/2 "you need to feel that you have achieved something"

[ex-pupil]

17/8/2 "if they gain success then they gain the right attitude toward the subject"

[experienced secondary teacher]

To be able to relate the experiment to the real world also seems to be desirable.

We have asked many ex-pupils what was the best moment they had experienced in their school science programmes. Although they all went to quite different schools at least one in five mentioned one specific experiment, 'the day we made hokey-pokey'. One 20 year-old told us that one of the big disappointments of science to him was that his class didn't make hokey-pokey while all his friends in other classes had. Others have mentioned the day 'we made soap', or 'the day we made nylon'.

36/7/1
22/13/2
15/1/2
11/1/2
20/17/2

36/7/2 "see like in the third form we made hokey pokey and that was really good because firstly we were having this real big thrill about making something to eat and secondly is that it was really dramatic...I mean hokey-pokey making is really dramatic and thirdly is that we were all made to sit down and write up the equation of the basic thing that was happening to make it all puff up and that was good because as we were sitting there munching away we learned something and it was fun...it was tasty and it was really interesting ...we could all go home and say whow! this is what we did today mum..."

[ex-pupil]

What are the essential ingredients which make this experiment so satisfying? Presumably children can identify with the task, "we are going to make hokey-pokey". The task relates to their world - we are all interested in food. The task was within the capabilities of the children. The children *succeeded* in the task, and it could also be related back to chemistry theory for the brighter student.

Just as we may need particular experiments to develop process skills, or at least experiments where the prime aim is to develop process skills, so perhaps we need to ensure that we have experiments in the programme where the prime aim is to develop positive attitudes to, and confidence in, science and the study of science.

WHERE DO WE GO FROM HERE?

The above comments and observations raise a number of questions

(i) Do we really need to consider further what pupils and teachers see as the purpose of experimental work? What is the place of experimental work in the teaching of science according to teachers? What do the pupils see as the teacher's aim in asking them to do experimental work? What do pupils see as the purpose of experimental work?

(ii) Should we investigate further through classroom observation some of the following. How frequently is the discovery approach forced by the teacher to unjustifiable conclusions? How frequently is the real point of the experimental work not understood by the student (or the teacher)? How frequently is there insufficient post-experiment discussion so that the purpose of the experimental work is not accomplished? How frequently are process skills specifically taught? How frequently are good scientific habits positively encouraged and bad habits positively discouraged? How frequently do children really appreciate the problem being experimentally investigated?

In terms of the action research phase of the project a number of possible measures which may help alleviate some of the identified problems need to be proposed and tried out. For example,

(a) One might conjecture that experiments are perceived as useful activities for students because in theory they provide a non-zero probability of developing all science objectives, e.g. knowledge, process skills, scientific habits and attitudes to science. However, it does seem that at least in some cases the attainment of some objectives is adversely affected as we try to achieve others. While everyone uses the word 'experiments' perhaps this is unfortunate and we should ban the word. Where the teaching of concepts and principles of science is the main objective we might replace 'experiments' by *laboratory experiences* and *discussion*. Where the development of process skills is the main objective we might replace 'experiments' by *investigations* or *projects* where the children find out for themselves without the threat of not getting the 'right answer' hanging over their heads. Finally, where attitudes toward science are the main objectives, we might replace 'experiments' by *happenings* or *field trips*. If this idea is supported, teachers need resource materials particularly for investigations, projects, happenings and field trips, as well as guidance as to what experiential learnings should support the learning of specific concepts and principles.

(b) It does seem that one real problem is to obtain suitable laboratory work which children can become enthusiastic about, which is at a suitable level for them, which motivates them, and which they can relate to their experiences and knowledge of their world. Perhaps children need to be more involved with the teacher, in discussing *how* they might *design* experiments, rather than being given instructions to follow. Would more of a problem solving approach to experimental work help? Can teachers be encouraged to clarify more clearly in their own mind why they are getting children to do a particular experiment and then encourage children to identify with that aim? How can a teacher cope when he or she has a wide ability range in the class? What type of experimental work for what type of pupil?

It seems to us that experimental work is a major and widespread problem in the teaching and learning of F1-4 Science. Do you agree? Have we identified the key aspects of the problem? What aspects of the problem have we overlooked? Where *do* we go from here?

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APPENDIX: Extracts from observers notes including transcripts

Appendix A1: An example of the problem of 'control' in experimental design

Observer in classroom (reading from F3 pupils notebook) - 'There was no glucose in the control tube.'
Observer: What's the control tube?
P1: Was that the beaker?
P2: Another tube or something.
P1: Oh yes we had to put in a test tube with something else inside it.
Observer: So this control tube is a special tube or what?
P2: No its just an ordinary tube.
Observer: Why is it called a control tube?
P1 & P2: Shrugs and giggles.

Appendix A2: An example of the problem of following instructions

Observer in classroom of 30 children working in pairs
Observer: What are you doing at the moment?
P1: Um ... that one there (points to step 3 in book) No. 3.
Observer: What is that?
P1: (Looks at partner who offers no comment, then picks up book).
Observer: Can you tell me without reading it?
P1: I've forgotten.
Observer: What is the whole experiment about?
P1: No response, grins.
(Later same pair of boys are heating a yellow solid)
Observer: What are you doing now?
P1: Heating this.
Observer: I see, what for?
P1: Well ... (races off to desk on other side of room bringing back book) we are doing No. 5.
Observer: What did you do before you started heating it?
P1: These ones here (points to No.3 & 4 of instructions).
Observer: Can you tell me what you have found out?
P1: We got this yellow stuff.
Observer: Can you tell me the purpose of this activity?
P1: No ... not really.

Appendix A3: An example of the problem of the 'right answer'

3 form class: 22 children working in groups of 2 and 3 using ASEP booklets,
Experiment: Heating up copper carbonate and getting the idea it converts to copper oxide and carbon dioxide. CO_2 tested with litmus in mouth of heated test tube.
Subjects: 2 Girls working on their own.
Observer: Can you tell me what you are doing?
P2: You put this in, and then you put it over the flame and we wet some of this paper and stick it in and see how it changes ... but we left it too long and all the gases escaped.
Observer: I see, you were supposed to test for gases with it?
P2: Yes, see what colour the gases change it (the litmus paper).
Observer: Are you going to try it again?
P2: Yes.
P1: (About to repeat experiment) Right now ...
P2: Hang on we have got to read it again. (re-reads instructions
P2: Shake it a little time.
Observer: What have you got in there do you know?
P2: (Reads from book) Copper carbonate.
Observer: What is that?
P1: A mixture of copper and carbonate. I don't know.
Observer: It changes colour anyway ... what do you think is supposed to happen (to the litmus).
P2: It is going to change colour : the gases will change it, hopefully.
Observer: What colour is it going to change to?
P2: A different colour to what it is!

Observer: You hope.
P2: Yes. (Heat it for some time)
P2: Hmm ...
P1: Go and get some dye and we will dye it:
Observer: Perhaps you were a bit late again do you think?
P2: We stuck it in straight away.
P1: Hang on I will get a new piece of paper.
P2: That's two failures in a row!
P2: We are jinxed!
Observer: When should it (the litmus) change. While it (the gas) is changing or after it has changed.
P2: When it first gets going because then all the gases come off.
P1: Third time lucky Aileen. (suggesting they try a third time).
(futile attempts to get colour change)
P1: Lets go and ask xxxxx
(Students go off to ask the teacher what should have happened)

(Later)
Observer: What did xxxx say?
P2: Um. It is supposed to turn pinky-red. (re-attempt the experiment for the third time).
P1: I know why it isn't changing because of the stuff around there ... (points to odd bits of copper carbonate on sides of tube).
P2: No ... because the gas is still going to come out ... it has still got to come out. (Attempt continues with no change of paper colour).
P1: How do we get all the dud pieces of indicator paper.
P2: Hm ...
P1: Oh it is not going to work Aileen ... we will just pretend it changed.
P2: Yes.
Observer: Is that what you do when it doesn't work ... pretend it worked ... so what do you write down? What do you think should have happened?
P1: Yes ... we found out nothing.
P2: Oh it is not going to happen ... too bad.
(Giving up heating)
Observer: What happens if you write down what actually happens.
P2: Giggle. Shrug.
Observer: Why do you feel you have to write down what should have happened rather than what actually happened?
P2: Because it would be a waste of time ... we would be doing it for nothing.
Observer: I see if you wrote down what you got rather than what you should have got.
P2: Yeh ... so now we know we are failures.
Observer: And nobody else is going to know if you write down what you should have got is that right?
P2: Yes.
P2: (Not clear) If we write down what we should have got then she'd (the teacher) think it's what we would have got, then we get more points!
Observer: Oh well I wonder if any one else got it (to change) or do they all do what you do.
P1 & P2: Laughter.
(Later talking about this to 2 fourth form girls)
Observer. ... what when she wrote it up she was going to say it had changed to pink.
P5: Well you have got to, because that is the right answer - you see a lot of us ask our friends if we don't know what it is and we just put down what everyone else puts.
Observer: I see so you don't put down what you actually got.
P6: No.
Observer: You put down what you have supposed to have got.
P5: Yes...
Observer: Do you think that is good science or not?
P5: No not really but you have got to learn what you put down.
P6: Better than nothing I guess.
P5: (Otherwise) it gets us stuck when we get a test.
Observer: So in the test you would have to know that it changed to pink. You would get it wrong if you put down what you actually got would you?
P6: Yes.